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THE ARC SPECTRUM OF HYDROGEN.

By O. H. Basquin.

With Two Plates.

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THE ARC SPECTRUM OF HYDROGEN.

By O. H. Basquin.

Presented by C. R. Cross. Received June 8, 1901.

The Problem.

The arc spectra of those elements which are gases at ordinary temperatures and pressures have not been extensively studied. Their spark spectra, however, are easily obtained, and were among the first to be investigated. The general impression prevails, therefore, that these elements do not possess arc spectra. On the other hand practically all the so-called "hot stars" and all the "new stars" possess the more important lines of the hydrogen spectrum. Although our knowledge of what is going on in the arc and in the spark is very crude and unsatisfactory, yet it is, to the average mind, much easier to imagine a star as being in a condition similiar to that of the arc, rather than in one similar to that of the electric spark. It has seemed worth while, therefore, to search for the more important lines of hydrogen in the arc spectrum. This is the problem of the following investigation.

Historical.

Liveing and Dewar * examined the carbon arc in an atmosphere of hydrogen and saw "the fairly bright" C line of hydrogen, also "a faint diffuse band" at the position of the F line of hydrogen. They obtained these two lines also by allowing small drops of water to fall into the arc in air.† They found the F line usually obscured by continuous spectrum, becoming visible at intervals only, when, from some variation in the working of the arc, the continuous spectrum was less brilliant. Crew and Basquin ‡ incidentally noticed these two lines of hydrogen while working with the rotating metallic arc in an atmosphere of this gas.

* Proc. Roy. Society, **30**, 156 (1880). † Ibid., **35**, 75 (1883).
‡ Proc. Amer. Acad., **33**, 18 (1898).

Apparatus.

In searching for these lines I have employed the rotating metallic arc,* which enables one to use chemically pure electrodes having little or no chemical reaction with the gas employed. In this arc, then, one may expect the gas to give off its characteristic radiations with greater intensity than in one where the gas may enter into chemical compounds before a temperature is reached at which it becomes luminous. This arc enables one also to select such metals as do not have strong lines in the neighborhood of the lines sought for, while in the spectrum of the carbon arc there are few spaces not already occupied by lines of carbon or of an impurity.

In the rotating arc, one electrode, either a disc or a rod of metal, rotates upon an axis, making about 700 rotations per minute, while the other electrode has a slow movement of translation toward the axis of rotation. The rotation not only prevents the excessive heating and welding together of the electrodes, but it throws the hot gases to one side, so that the arc has the appearance of a small fan. The part of the flame thus separated from the poles is very free from continuous spectrum.

In the apparatus used in these experiments the arc is enclosed in a brass box, or "hood," having a volume of about 1½ litres and being comparatively gas-tight. The light from the arc issues through a long brass tube closed with a lens at the outer end; the lens thus forms part of the wall of the hood, but is so far removed from the arc that it receives comparatively little of the deposit sometimes formed inside the hood, and hence remains clean.

A stream of gas enters the hood at one stop-cock and leaves it at another; a third cock is provided for attachment to a manometer. Although the hood is not absolutely gas-tight, the purity of the gas inside was preserved, in these experiments, partly by the small excess of pressure inside the hood above that outside, and partly by the fresh supply of pure gas constantly running through the hood. The hydrogen used was generated electrolytically, and varied in quantity from 10 to 15 litres per hour.

The spectra have been examined both visually and photographically by means of a small plane grating spectroscope and by means of a large concave grating spectroscope.

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* Crew and Tatnall, Phil. Mag., **38**, 379 (1894).

Observations of Hydrogen Lines.

The arc spectra of the following metals in hydrogen have been examined: Aluminium, copper, magnesium, coin-silver, sodium, tin, and zinc. With the exception of sodium the arc of each metal shows to the eye very clearly the H_α and H_β lines of hydrogen, and in most of them the H_γ line comes out with the small instrument very clearly, and indistinctly with the large one. The H_δ line shows only rarely, and then to the eye rather indistinctly. The H_α line is quite sharp and well defined, unless the electric current through the arc is unusually great; it has much the same appearance as the zinc line at 6363. The other three are always broad, hazy, and ill-defined.

On the photographs taken with the large spectroscope H_β and H_γ usually show very plainly, always excepting the spectrum of metallic sodium, while H_δ shows in spectra of tin, silver, and copper. On photographs taken with the small spectroscope these lines show more sharply, on account of the very much smaller dispersion, and the photographs of tin show the next hydrogen line, H_ϵ quite clearly. Not having found the hydrogen lines in the metallic sodium arc (using copper as stationary electrode), I tried it in dry hydrogen also, thinking that in some way the water vapor might have affected the appearance of the hydrogen lines, but I have been unable to detect any of the hydrogen lines in that arc in any way.

None of these lines excepting H_α is sharply defined. A wide space in the middle of each line has fairly uniform intensity, shading off gradually and uniformly to each side. The following table gives a rough estimate of widths, in Ångström units, of these lines as they appear on the photographic plates, the middle of the shading being taken as the edge of the line.

Line.	Maximum width.	Minimum width.	Mean width.
H_α	6	4	5
H_β	65	13	31
H_γ	44	14	26
H_δ	32	12	20
H_ϵ	faint, same general width.		

It will be noticed that these lines, with the exception of H_α, are excessively wide, and I think it is for this reason alone that I have been unable to photograph the still weaker hydrogen lines of Balmer's series.

They may appear upon the plates, but are so wide and so faint that they cannot be detected upon the general shading of the plates.

That these lines are not merely spark lines introduced into these arc spectra by the supposed spark at the breaking of the current through the rotating arc is shown, first, by the fact that they were first observed in the carbon arc, and, second, by the fact that I have seen H_α and H_β quite clearly in the magnesium metallic arc, when the poles were not rotating. The lines produced in the stationary arc have much the same character as in the rotating arc, but there is a large amount of continuous spectrum, appearing as a background, in the case of the stationary arc, so that it would be difficult to photograph the hydrogen lines in this way.

These lines in the arc seem to be due to hydrogen, and not to water vapor coming from the hydrogen generators.* This is shown by the following two experiments: (1) I passed the stream of hydrogen through concentrated sulphuric acid and phosphorus pentoxide; and even after the stream of dry gas had been running through the hood for three hours, I found the H_α line as bright as it was in the damp hydrogen coming directly from the generators. (2) In place of the current of dry hydrogen, I passed through the hood a stream of air bubbling through warm water, so that this air was charged with moisture to about the same degree as the moist hydrogen coming directly from the generators. In this case I was not able to detect the faintest trace of the H_α line. Magnesium poles were used in both the above experiments.

Other Methods.

I have examined some of these metals in commercial ammonia gas, such as is used in refrigeration. In this gas the hydrogen lines come out with nearly the same intensity as in hydrogen when copper or aluminium electrodes are used; no hydrogen lines are seen in the sodium arc in ammonia, although the arc works well, and when tin electrodes are used in ammonia a black dust collects in the atmosphere about the arc to such an extent as to shut off practically all the light within thirty seconds after starting the arc. From the standpoint of convenience and safety, the ammonia gas is much to be preferred to hydrogen.

The copper arc in coal gas shows the H_α line very clearly, but the other hydrogen lines are not distinguishable on account of the multitude of comparatively strong carbon lines which the coal gas furnishes in this part of the spectrum.

* Trowbridge, Phil. Mag., **50**, 338 (1900).

Following the suggestion of Liveing and Dewar, above referred to, I have tried the rotating metallic arc in air, playing a very small jet of water upon the rotating electrode. In this manner the silver arc works rather more poorly than usual, and resembles a rapid series of small explosions. The hydrogen lines come out clearly, but are rather weaker and more diffuse than in the hydrogen atmosphere.

The copper arc works well in an atmosphere of steam, much better than in hydrogen. The hydrogen lines are nearly, if not quite, as strong in steam as in hydrogen. The electrodes of the arc are slightly oxidized and have very beautiful colors. In making this experiment a slight alteration was necessary in the hood of the arc. The window through which the light issues is usually as far away from the arc as possible, but it was moved for this experiment so as to be as close to the arc as possible. It was placed at the inner end of a brass tube projecting into the hood, in order that the heat of the surrounding steam and hot air, as well as that of the arc itself, might prevent condensation of steam upon the surface of the window.

CHEMICAL ACTION IN THE ARC IN HYDROGEN.

Historical.

Crew and Basquin * have sought to eliminate the radiations due to chemical causes in the electric arc by using chemically pure metallic electrodes and enclosing the arc in an atmosphere of hydrogen or nitrogen. They interrupted the current through the arc about 110 times per second and examined the light of the arc while the current was null. They found in the rotating metallic arc *in air* "a luminous cloud" persisting for several thousandths of a second after the current through the arc had ceased, but they found no such luminous effect in an atmosphere of hydrogen or nitrogen. This seems to show that the cloud is due to chemical action going on in the gases after the electric current has stopped, and that in hydrogen the chemical action is too feeble to be noticed in this way.

Liveing and Dewar† found a magnesium "line" at 5210, making its appearance in the arc spectrum only upon the introduction of hydrogen or coal gas into the arc. Professor Crew ‡ gives a number of lines appearing in the iron arc in hydrogen and not appearing in the arc in air.

* Proc. Amer. Acad., **33**, 18 (1898).
† Proc. Roy. Society, **30**, 96 (1880).
‡ Phil. Mag., **50**, 497 (1900).

Hydrogen-metal Flutings.

With the exception of tin, every metal thus far examined in the rotating metallic arc in hydrogen gives a characteristic set of spectrum lines which are not found in the arc in air. Inasmuch as compounds of hydrogen with some metals are known, I have, in lieu of a better hypothesis, supposed that these lines are due to such compounds formed in the arc. No new isolated lines, surely due to hydrogen, have been found. The following description takes up the metals in the order of the relative intensities of these flutings.

Tin.

No fluting has been discovered due to a combination of tin and hydrogen. There are four lines of intensity ½ on Rowland's scale, at approximately 3715, 3841, 4245, and 4386, which have not yet been identified. These may be weak tin lines not listed, or weak impurity lines. The deposit which is formed in the hood enclosing the arc is very small in amount and of a greenish color, and consists of very small globules. If this deposit is heated upon platinum foil in a Bunsen flame it quickly glows, and thereafter has a slate color; and if this powder is placed in hydrochloric acid it dissolves when heat is applied and gives off bubbles of gas. If the dark powder, after the first heating, is reheated on foil in the flame, it glows again, apparently at a higher temperature than before, and then becomes a very white powder, both of which experiments go to show that the original powder is not metallic tin but is possibly some combination of tin and hydrogen.

Coin Silver.

This metal gives a delicate fluting with first head at 3333.86 and running toward longer wave lengths. There are only about fifty lines in this fluting, and they have an average intensity rather less than ½ on Rowland's scale.

Copper.

This metal gives a rather open fluting, having the head at 4279.77 and running toward the longer wave lengths. The number of lines in this fluting is about sixty, and they are individually stronger than those of the coin-silver fluting. This fluting makes its appearance also when an atmosphere of ammonia or of steam is used. The deposit formed inside the hood is rather small in amount and of a brown color. The following table gives the wave lengths of the hydrogen-copper flutings: —

Wave lengths.	Intensity.	Remarks.	Wave lengths.	Intensity.	Remarks.
4279.77	2	head.	4332.98	1–	
4280.72	1		4335.20	1+	
4281.25	1+	ghost of 4275 ?	4339.80	1–	
4281.85	1+		4341.98	1+	
4282.48	½		4347.06	1–	
4283.38	1+		4349.13	1+	
4284.15	½		4354.59	1–	
4285.26	1+		4356.73	1+	
4287.58	1+		4364.68	1+	
4290.25	1+		4373.01	1+	
4293.45	1+		4381.70	1+	
4294.86	1–		4382.92	½	hazy
4296.98	1+		4384.74	1–	
4298.55	1–		4390.	—	very indistinct.
4300.92	1+		4390.85	1+	
4302.63	1+		4400.30	1+	
4305.24	1+		4405.04	1–	
4307.07	1+		4410.12	1+	
4309.98	1		4413.09	½	
4311.89	1+		4420.42	1+	
4315.12	1		4421.59	1–	
4317.07	2	slight shading toward	4430.94	1	
4820.68	1–	[blue.	4436.48	1	
4322.74	1		4447.18	½	
4324.59	1+		4453.30	1	
4326.61	1		4458.03	1	
4328.77	1+		4465.01	1	
4331.38	½	hazy.	4477.15	1	

Aluminium.

The aluminium arc in hydrogen gives a beautiful fluting with first head at 4241.26 and running toward longer wave lengths. This fluting appears equally well in an atmosphere of ammonia. The following table gives the wave lengths and intensities of the principal lines: —

Wave lengths.	Intensities.	Remarks.	Wave lengths.	Intensities.	Remarks.
4241.26	3	1st head.	4248.09	2	
4241.75	3		4249.68	2	
4242.41	2		4250.34	1	
4243.10	2		4251.44	2	
4243.94	3	wide.	4253.26	2	
4245.82	4		4255.22	2	
4246 58	3		4257.35	1+	
4247.58	1		4259.71	3	wide, 2d head.

Wave lengths.	Intensities.	Remarks.	Wave lengths.	Intensities.	Remarks.
4261.18	3		4315.57	3	
4261.77	3		4320.63	3	
4262.59	3		4326.00	5	impurity superposed.
4263.50	3		4331.91	2	
4264.58	3		4338.37	2	
4265.80	3		4345.34	1	
4267.24	3		4353.38	2	4th head.
4268.86	3		4354.13	1	
4270.68	3		4355.17	1	
4272.72	3		4356.64	1	
4274.98	5	impurity here.	4361.30	1	
4277.70	4	impurity here.	4362.21	1	
4280.67	4		4363.50	1	
4283.94	4		4365.18	2	
4287.30	2	3d head?	4367.21	2	
4287.75	3		4368.	½	
4289.91	3		4369.67	2	
4290.68	2		4371.49	½	
4292.01	2		4372.54	1	
4294.31	3		4375.18	½	
4296.99	2		4375.97	1	
4298.10	3		4379.19	½	
4302.08	3		4379.90	½	
4302.65	1		4388.23	1	
4306.34	3		4393.42	1	
4310.82	3		4399.19	1	

Magnesium.

The magnesium arc in hydrogen gives the three flutings discovered by Liveing and Dewar * in the magnesium-hydrogen spark, with first heads at 5618, 5210, and 4849, and running toward the shorter wave lengths. The fluting at 5210, which is the one showing the plainest on my photographs, is made up of such very fine lines near the heads that the principal head appears like a line by itself; but farther away from the heads the lines seem to become stronger and to overlap one another, so that many of these lines are much stronger than the head itself and their distribution seems quite irregular. I mention this more particularly because it is characteristic of the hydrogen-zinc and hydrogen-sodium flutings described below. I have noticed that in the spark, the intensity of the magnesium flutings is greatly increased with respect to that of the "b" group by the introduction of inductance in series with the capacity

* Proc. Roy. Society, **32**, 189 (1881).

shunted about the induction coil. The deposit in the hood enclosing the magnesium arc in hydrogen is quite plentiful, has a dark slate color, decomposes water at ordinary temperature, giving alkaline reaction, and oxidizes rapidly on heated platinum.

Zinc.

The zinc arc in hydrogen gives a collection of lines between 4300 and 4050, having an average intensity from 2 to 4, and not found in the arc in air. This appears to be a set of flutings of complicated structure having heads less distinctly marked than usual and running toward the shorter wave lengths. The semi-opaque deposit formed in the atmosphere of the hood is so considerable that a current of not more than about four amperes can be used. This deposit is dark brown in color, gives alkaline reaction in water, but does not decompose it enough to form bubbles even when heated. It dissolves completely in sulphuric acid, forming a clear solution, and rapidly oxidizes on heated platinum.

Sodium.

The sodium spectrum was obtained by using metallic sodium as the cooler rotating electrode and copper as the stationary one. As above mentioned, there is not the slightest trace of any of the hydrogen lines to be detected in this spectrum either visually or on the photographs, but there is a strong series of lines between 5000 and 3800, resembling the hydrogen-magnesium series in character. This is probably a complicated fluting of heads less clearly marked than usual and running toward the shorter wave lengths. A compound of sodium and hydrogen is already well known. The formation of the semi-opaque deposit in the atmosphere of the hood is so considerable that the arc can be run only about five minutes at a time. I have not tried the sodium arc in air.

The sodium spectrum obtained in hydrogen is itself quite interesting. All the sodium lines given by Kayser and Runge * come out very clearly, but the principal interest centres about the D lines, which are very intense, and so wide as to cover all the region between them. When observed visually their reversals change in width quite rapidly. At first these reversals may be quite narrow black lines, and then they quickly widen and blot out the whole of the bright field between them. The width of the two lines taken together is about 150 Ångström units, though the photographic plates are stained for a much greater width.

* Kayser & Runge, *Weid. Ann.*, **41**, 302 (1890).

The strongest copper lines show only very faintly, the weaker ones not at all.

Correlation of Effects.

In the metals arranged in the order given above (tin, silver, copper, magnesium, aluminium, zinc, and sodium) the following relations hold roughly: —

(1) The set of lines characteristic of the spectrum of each metal in an atmosphere of hydrogen is stronger than that of the *preceding* metal of the series; (2) the hydrogen lines appearing in the spectrum of the metallic arc of each metal are stronger than in that of the *succeeding* metal of the series; (3) the general working of the metallic arc is worse for the metals at the first of the series than for those at the end. Briefly stated, the intensities of the hydrogen lines coming out in the spectra of various metals are roughly inversely proportional to the intensities of the characteristic flutings of those metals.

GENERAL EFFECTS OF THE HYDROGEN ATMOSPHERE.

Historical.

Liveing and Dewar * found the carbon arc to work badly in hydrogen, and to give spectral lines of different relative intensities than in air. Professor Crew † has given quantitative measurements of the changes of intensities for the metallic arc spectra of magnesium, zinc, and iron.

The general effects of the hydrogen atmosphere may be summarized thus: —

(1) The arc works poorly in hydrogen. (2) The intensity of the whole spectrum is greatly reduced in hydrogen. (3) Those metallic lines which belong to the series of Kayser and Runge are uniformly reduced in intensity. (4) Other lines are reduced in intensity but not uniformly. (5) Certain lines supposed to belong to the spark spectrum make their appearance in the arc in hydrogen.

Discussion.

The radiations of the electric arc are generally admitted to be due to three causes, — electrical, chemical, and thermal. The chemical cause must depend upon the electrical cause in some way, for the chemical cause

* Proc. Roy. Society, **33**, 430 (1882).

† Phil. Mag., **50**, 497 (1900).

cannot originate the arc, and the chemical cause follows the electrical in point of time, as is shown by the "luminous cloud" of Crew and Basquin above referred to. The thermal cause also must depend upon the electrical cause in some way. It probably depends upon it directly, but in any event, it is a function of it through the chemical cause, for all chemical reactions either take in heat or give off heat.

Let us consider two arcs which are alike except that a larger current runs through the first than through the second. Since the secondary causes of radiation go hand in hand with the electrical cause we may expect the first arc to have a spectrum which is uniformly brighter from one end to the other than that of the second arc. With the exception of a slight variation probably due to conduction losses, this is just what is always observed and confirms the secondary character of the chemical and thermal causes of radiation. If these causes were not dependent upon the electrical cause, we might possibly get an arc which would give only a flame spectrum or an arc which would give only a spark spectrum.

Let us now suppose that we run the same current through both the similar arcs, and suppose that in some way we reduce the chemical action going on in the second arc. What difference may we expect to observe in them?

A reduction of the chemical action necessarily involves a reduction of the temperature of the arc, because the chemical reaction in the arc in air is exothermic. We have then an arc of lower temperature. If it is a stationary arc it will be shorter and will go out more frequently. If it is rotating it will have a smaller flame and work more poorly. All of which is amply verified by experiments in hydrogen.

But we may expect this reduction of chemical action to have certain effects upon the spectrum. If all the lines of the spectrum of this arc were functions of the *electrical cause alone*, then there would be *no reduction* in intensity of any part of the spectrum when the chemical action is reduced. Professor Crew estimates from 5 to 100 times as the reduction in intensity caused by the hydrogen atmosphere. The electrical cause alone can account, then, for only a small part of the radiation. The secondary causes play very important parts.

If all the lines of the spectrum of this arc were the *same function* of the causes of radiation, then all the lines of the spectrum would be *uniformly* reduced in intensity upon the reduction of chemical action. Experiment shows this hypothesis to be too broad, but the lines belonging to the series of Kayser and Runge are uniformly reduced in intensity, so that it is *probable* that these lines are all the same function of the causes of radiation.

Of the other lines, those which are reduced more in intensity than the series lines, must be less intimately related to the electrical or thermal causes of radiation than are the series lines.

Let us agree that the average intensity of the spectrum of the arc in hydrogen is only one fifth of its intensity in air, and let us agree that the electrical cause of radiation remains practically constant with constant current and voltage although the general intensity of the arc is greatly reduced by the hydrogen atmosphere, then it follows that of the total radiation, that fraction which must be attributed to the electrical cause alone, is relatively five times as great in hydrogen as it is in air. Any line, therefore, which is a function of the electrical cause alone, should have in hydrogen five times the relative intensity that it has in air. It seems quite likely that this may account for the appearance in hydrogen of numerous strong spark lines, not found in the arc in air.

The appearance of the spark lines in hydrogen is not confined to the rotating arc; the magnesium spark line at 4481 appears clearly in the stationary metallic arc in hydrogen but not in air. The above explanation for the appearance of these lines makes it probable that the electrical cause of radiation is not zero in either atmosphere.

In the rotating arc the current is interrupted about twenty-five times per second when the rotating electrode is a rod, instead of a disc, of metal, and this spark at the breaking of the current may account, in part, for the appearance of these spark lines in hydrogen. But we may inquire why this spark should partake any more of the nature of the true spark in hydrogen than in air. The reduction of the chemical action in the arc reduces the temperature and conductivity of the gases between the poles in hydrogen, and it occurred to me that this action may affect the appearance of the spark lines in either of two ways: —

1. It may be that a gas which is in the hot condition of the arc in air cannot give off spark lines; the arc spectrum may be characteristic of this condition of the gas and may have nothing to do with electrical action, and so, in this state, would give off only arc lines if a spark were passed through it.

2. It may be that the conductivity of the gases in air is reduced so slowly at the breaking of the current in the rotating arc that the voltage of break never rises high enough to make a true spark.

In either of these cases, in hydrogen, the hot gases are largely absent, owing to reduction of chemical action, and give opportunity for the spark to appear.

In order to test the first suggestion I arranged an electrical circuit as

shown in the diagram. The dynamo furnishes a direct current of 110 volts, and when the switch was closed the current simply passed through the arc and the resistance in series. The arc was stationary, one electrode was carbon and the other a zinc rod. The induction coil used is a duplicate of the one designed by Professor Rowland to give a short

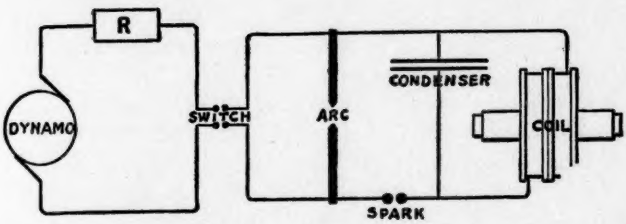

FIGURE 1.

spark but a very powerful discharge; an alternating current of 110 volts, 6 amperes, was run through the primary, without an interrupter. The condenser used has a capacity of $\frac{1}{30}$ microfarad. It will be noticed that the spark can take place only by passing in succession the two gaps marked "arc" and "spark." The spectroscope is adjusted to observe phenomena at "arc" gap.

In performing this experiment I first turned on the spark and set the cross-hairs of the eyepiece of the 10-ft. concave grating upon the zinc spark line at 5895, between the D lines of sodium. The spark was turned off and the arc turned on. The spark lines no longer appeared, but came out instantly when the spark was again started along with the arc; both arc and spark were now running through the gap marked "arc" and the spectroscope showed both arc and spark lines. Now while both currents were on, the arc current was turned off; the arc spectrum disappeared, but the spark spectrum persisted with apparently the same intensity as before and without an interval of darkness.

This experiment shows that the first suggestion is not true; that the arc spectrum is not characteristic of the condition of the gases in the arc, and makes it highly probable that the electrical cause of radiation is not zero.

In order to test my second suggestion above, I short-circuited the spark gap shown in Figure 1. The spark line appeared as before in the spark, but disappeared as soon as the arc current was made; the arc and the spark discharges were both passing through the arc as before; I had

simply cut out the "spark" gap, but the spark line could not be seen when both currents were on. Now when both currents were on I broke the arc circuit, and nothing at all could be seen in the spectroscope; neither the arc nor the spark lines remained, although the spark current was still passing. After remaining at the eyepiece of the spectroscope about one second I began to see traces of the spark lines, and then they soon came out with their usual brightness, and the spark discharge which had been silent during that second of darkness assumed its usual noisy character.

This experiment shows that the gases of the arc do not furnish enough resistance to the passage of a high voltage alternating current to cause the discharge to assume the character of a spark for a full second after the breaking of the arc current. This seems to confirm the second suggestion above, to the effect that the conductivity of the gases decreases so slowly on the breaking of the arc current in air as to give rise to no very high voltage, and so accounts for the non-appearance of the spark lines in the rotating arc in air.

These two experiments throw an interesting light upon the nature of the spark. The spark at the arc gap in these experiments seems to be due to neither the current nor to the voltage, but to some kind of an impulse furnished by the sudden rush of electricity across the auxiliary "spark" gap.

In the second experiment, above described, the spark lines do not all seem to come out at the same time. I hope in the near future to be able to arrange an automatic apparatus for making and breaking the currents and an adjustable occulting-screen which will enable one to photograph the spectrum of the spark at definite intervals of time after the arc current is broken. A series of these photographs will probably furnish an interesting story of the development of the spark spectrum.

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INDEX TO PLATES.

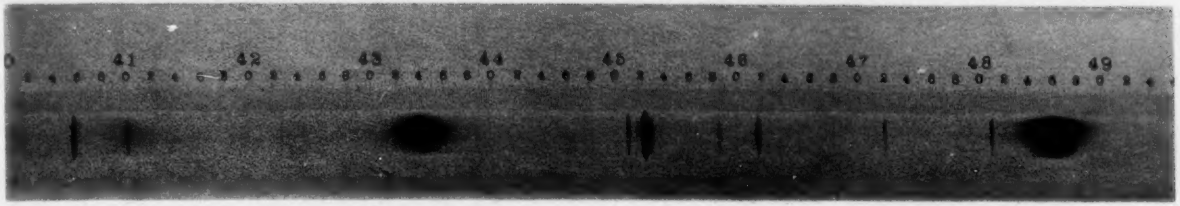

Fig. 1

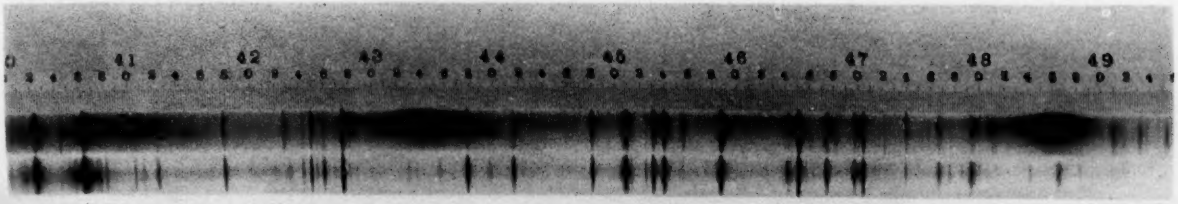

Fig. 2

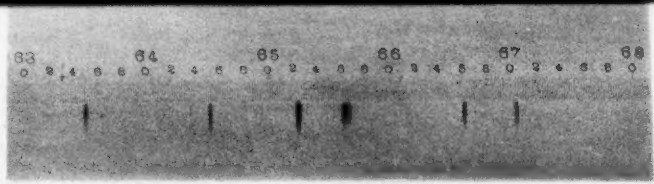

Fig. 3

Fig. 4

THE HELIOTYPE PRINTING CO., BOSTON.

Fig. 1

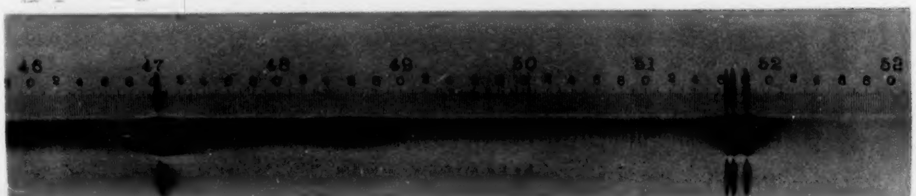

Fig. 2

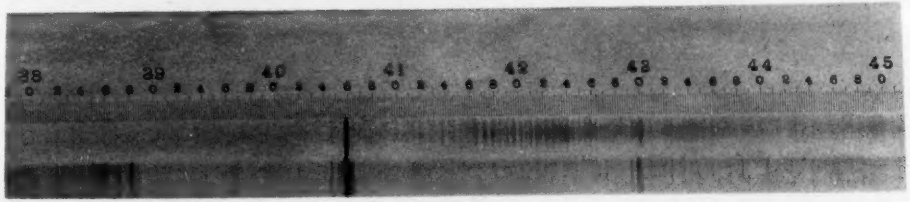

Fig. 3

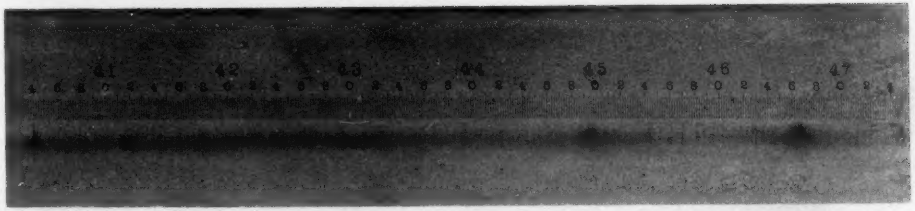

Fig. 4

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